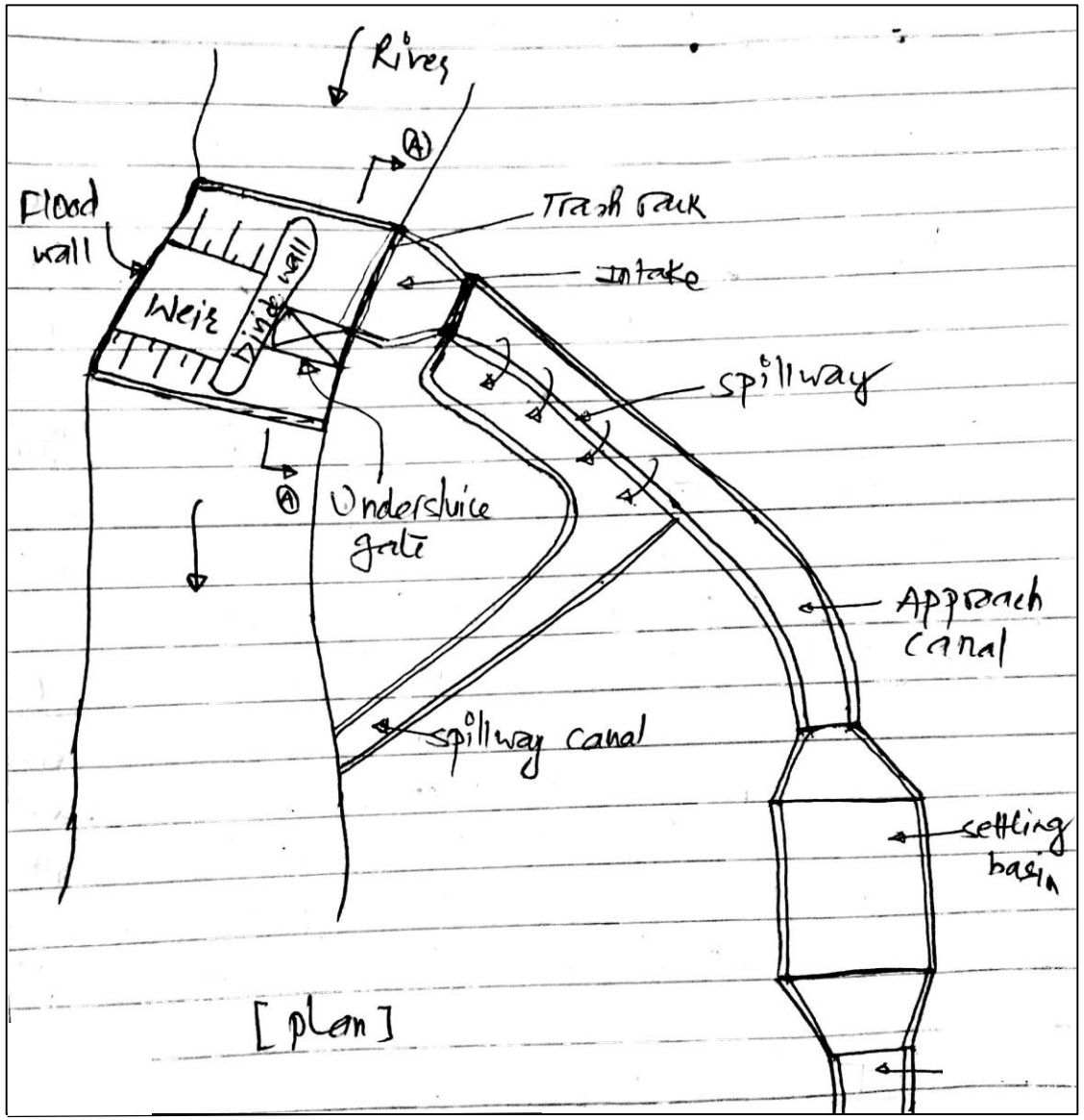
7.Headworks of RoR plants

- General arrangement of component of RoR plants:



Headwork of RoR plant extents from wear/ barrage to settling basin.

Main object:

To withdrawal the required amount of sediment free water from river.

❑General requirements of a functional RoR headwork:

1. Withdrawal of required amount of water
2. Flood bypass
3. Control of bed load
4. Control of debris cover, ice, trashes
5. Control of suspended particle
6. Minimum O/M
7. Minimize the hydraulic losses
8. Simple in construction &
9. Prevent formation of air vortices

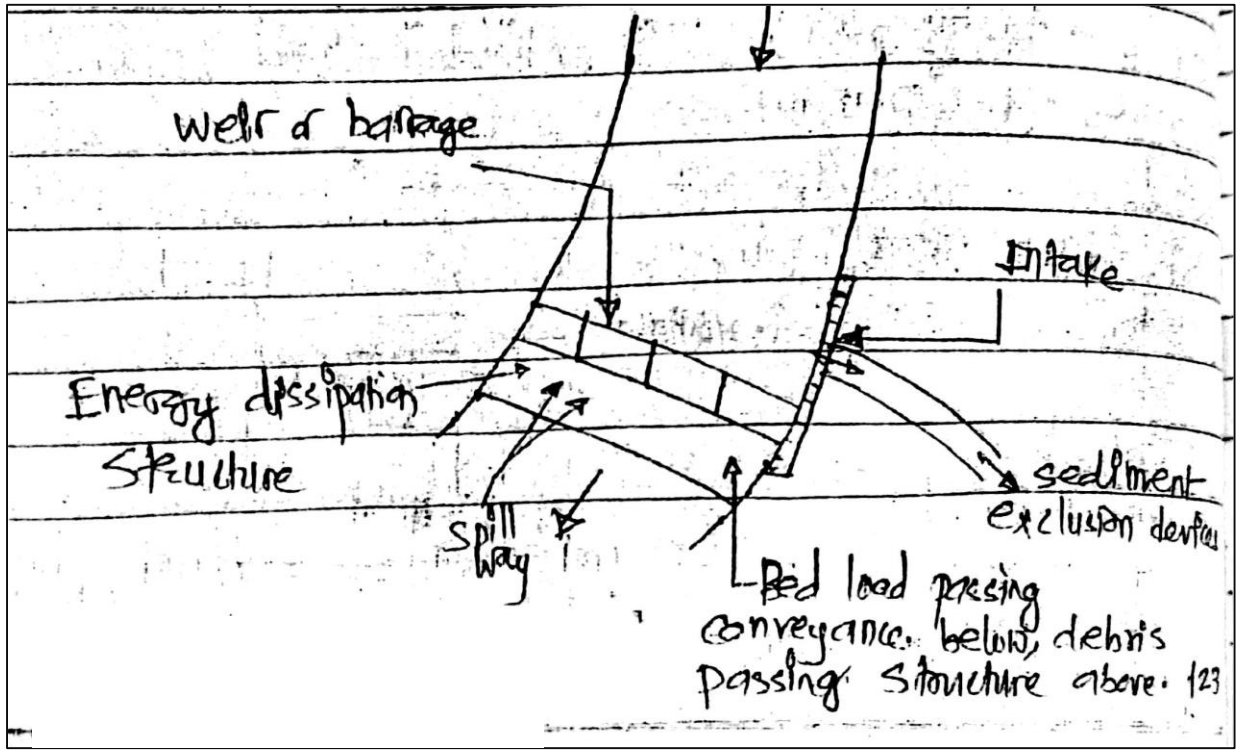
❑Intake:

Main objective of intake is to withdrawal of reqd. amount of clear water.

❖Types of intake

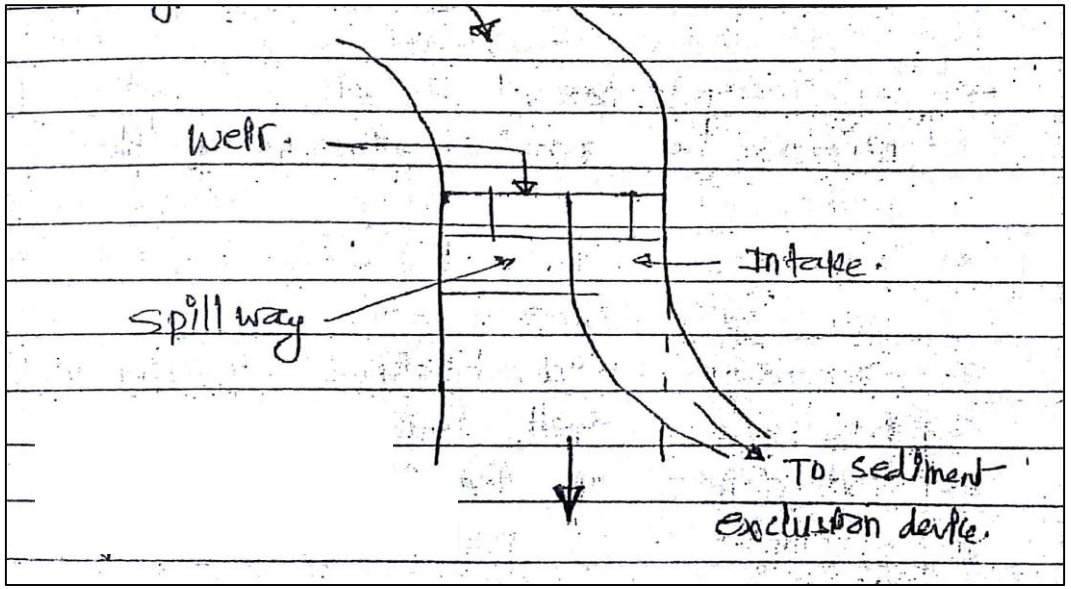
A. RoR intake:

(i) Side intake:



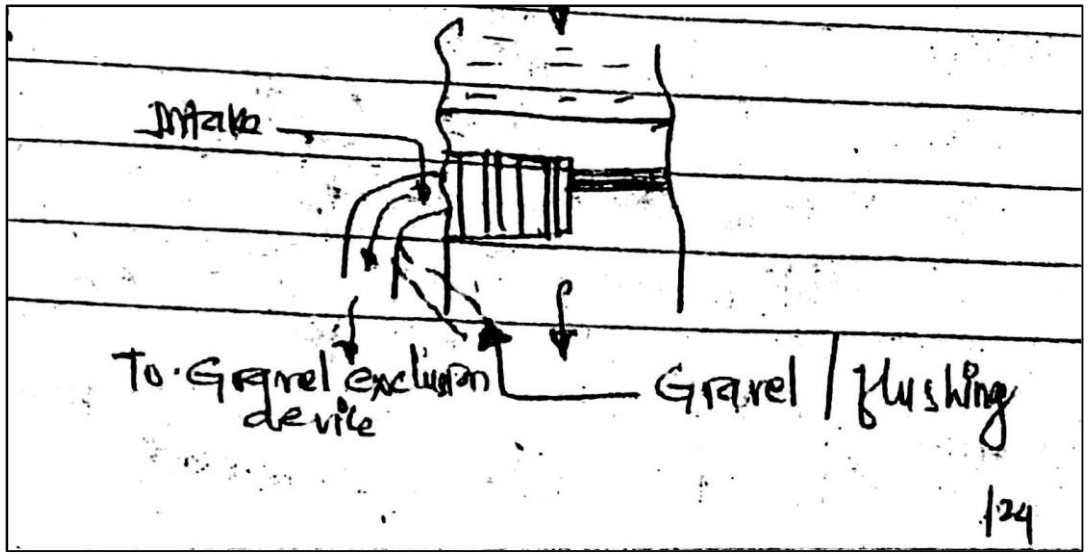
- Suitable for mild slope of river
- Eg. Sunkoshi (10.05MW), Lower Marsyangdi (69MW)

(ii) Frontal intake:



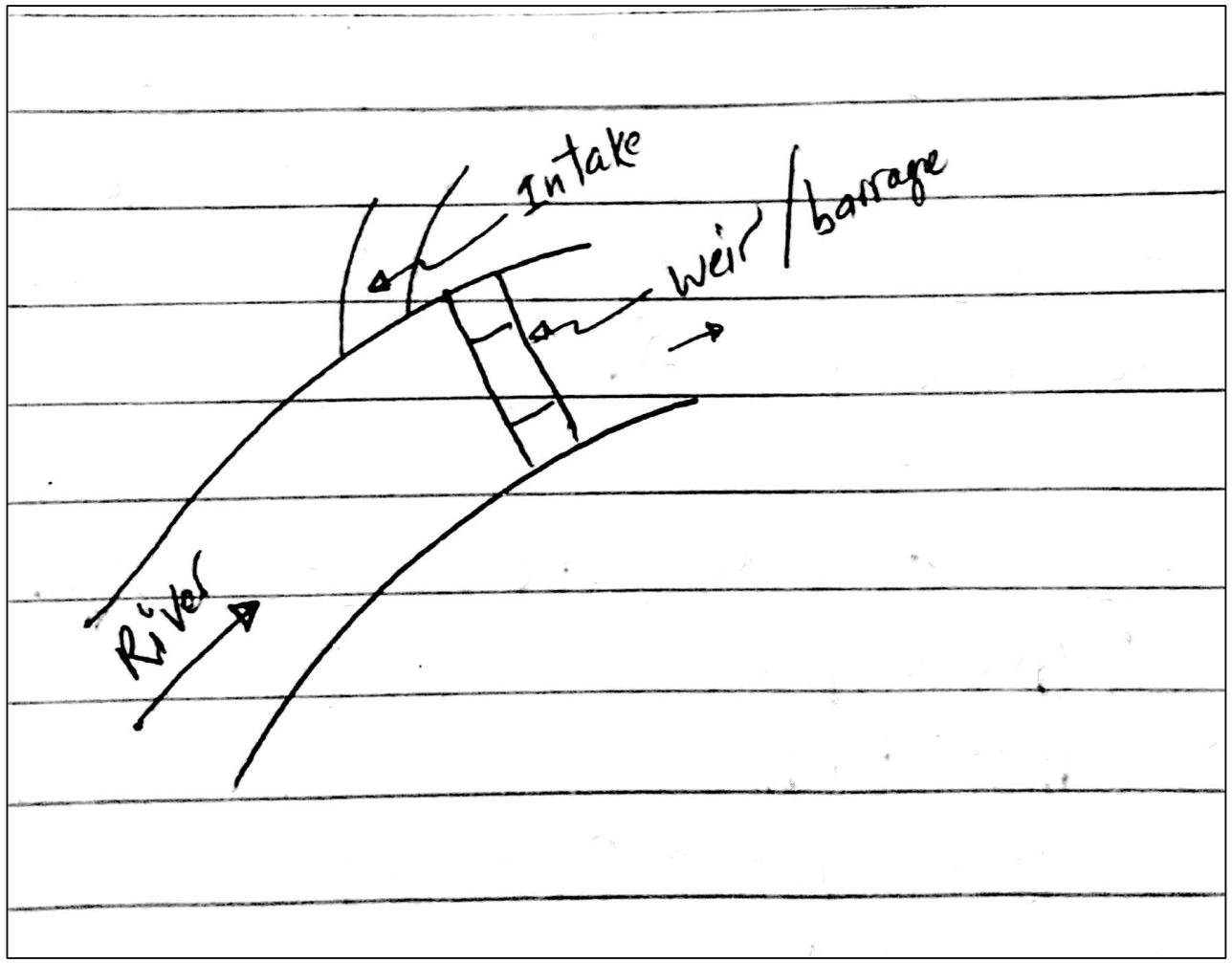
- Suitable for wide river and relatively clean water carrying river
- Eg. Pnauti (2.4MW)

(iii) Drop intake:



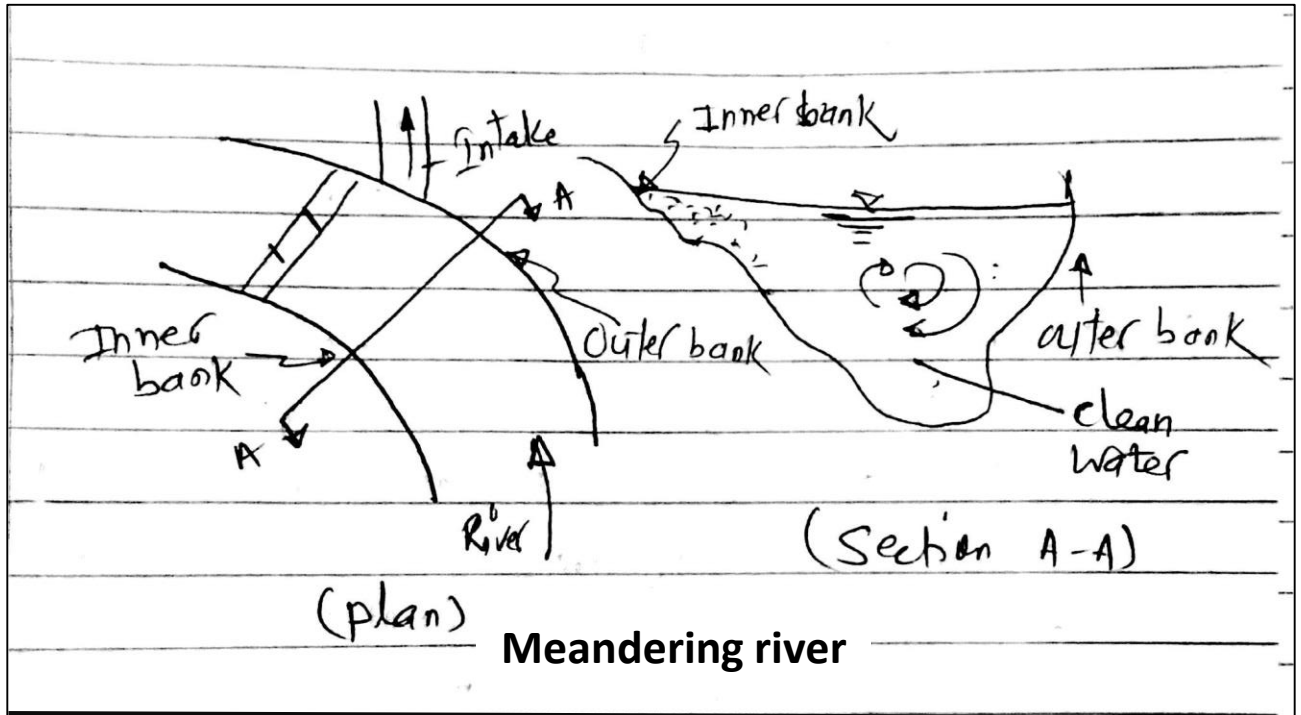
- Suitable for very steep rivers carrying boulders
- Main disadvantage is chocking of trash rack

(iv) Coanda intake:

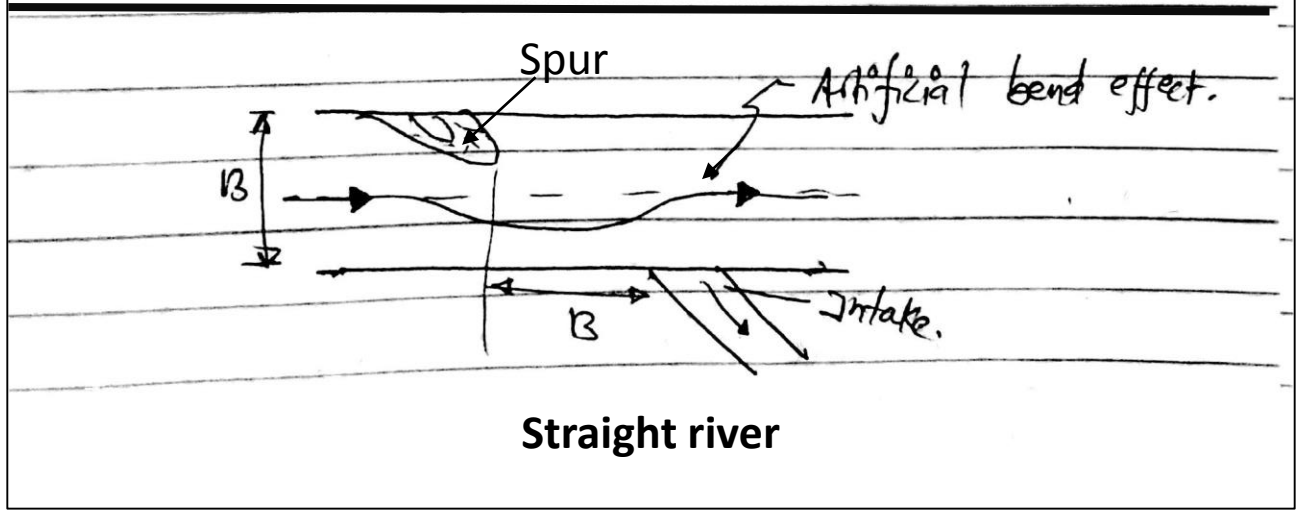


It is suitable for outer side of the natural bank having less sediment but with floating debris.

❑Location of intake:



Meandering river



Straight river

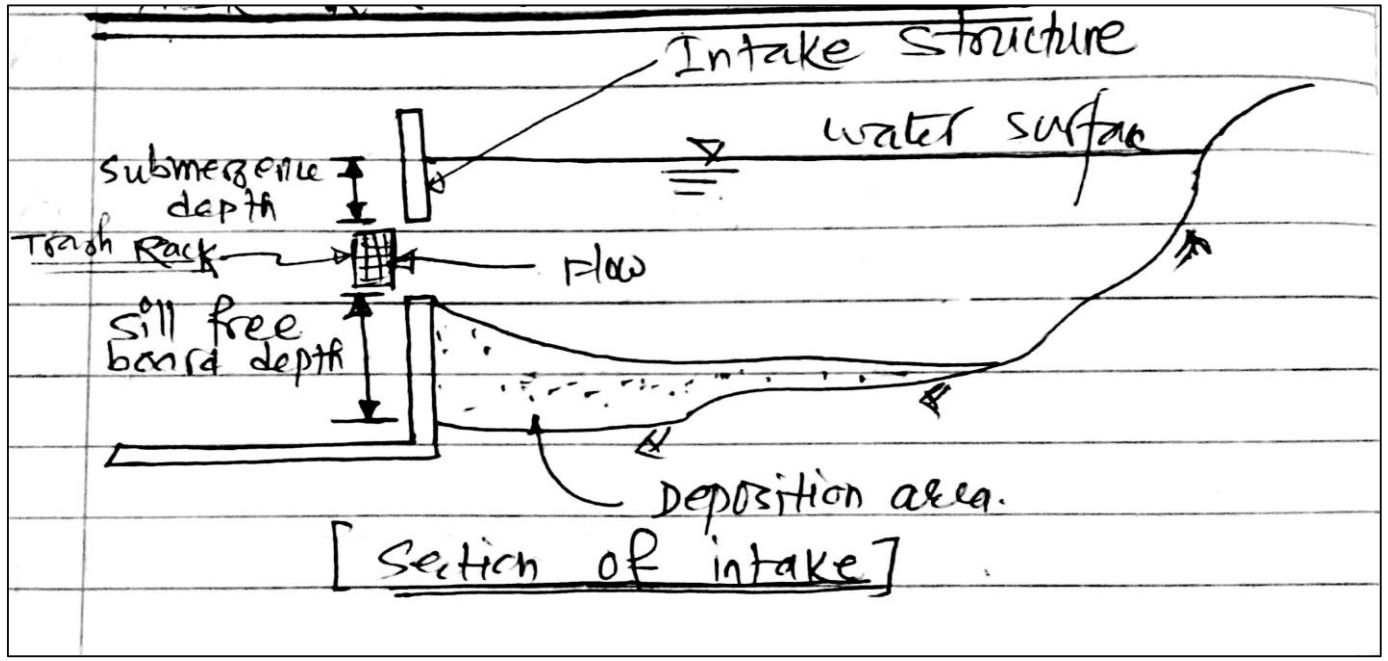
1. ***Meandering river:*** Intake is located at outer bank of river due to large amount of water and less sediment.

2. ***Straight river:*** Intake is located at a distance 'B' from the tip of spur at opposite bank of the spur.

❑Selection of type of intake:

1. Nature of river
2. Nature of scale of HP project
3. Construction consideration
4. Sediments, trashes and debris content &
5. O/M consideration

❑Control of sediment in RoR headwork intake:

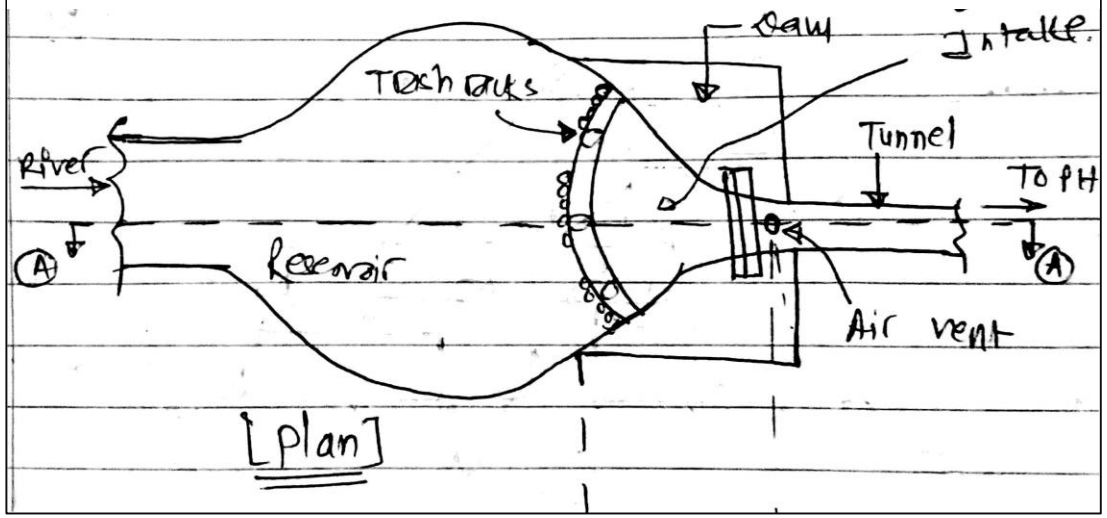


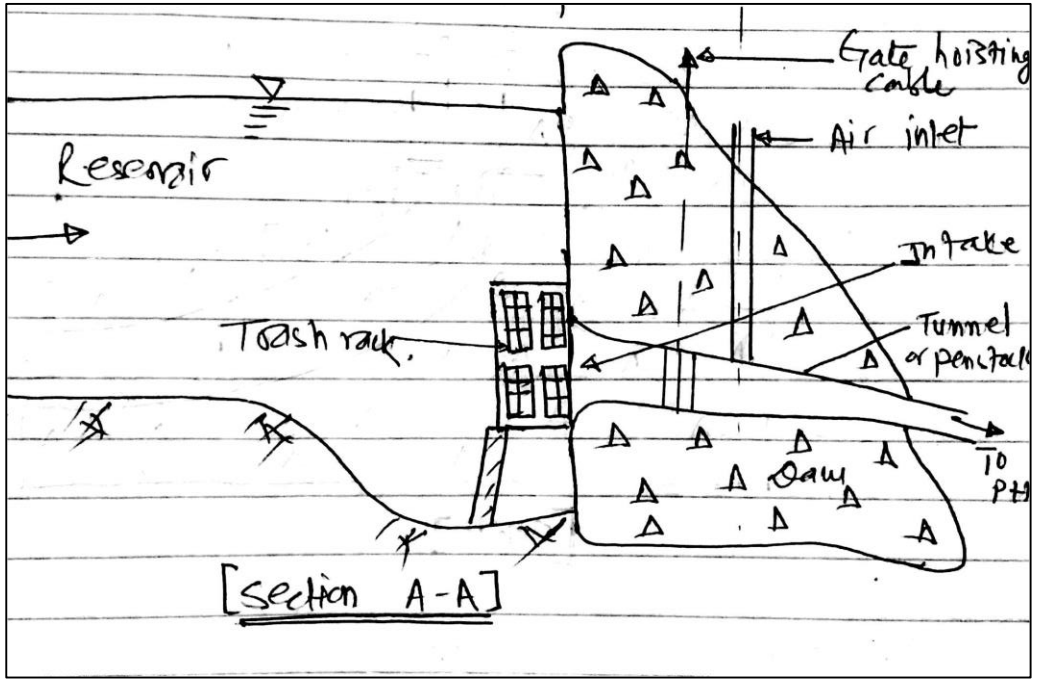
1. Select suitable location of intake
2. Control the bed load by using intake sill
3. Control of floating debris, ice, trashes etc. with the help of trash rack
4. Settling basin control
5. Power house should be shut down during high flood time.

B. Storage type of intake:

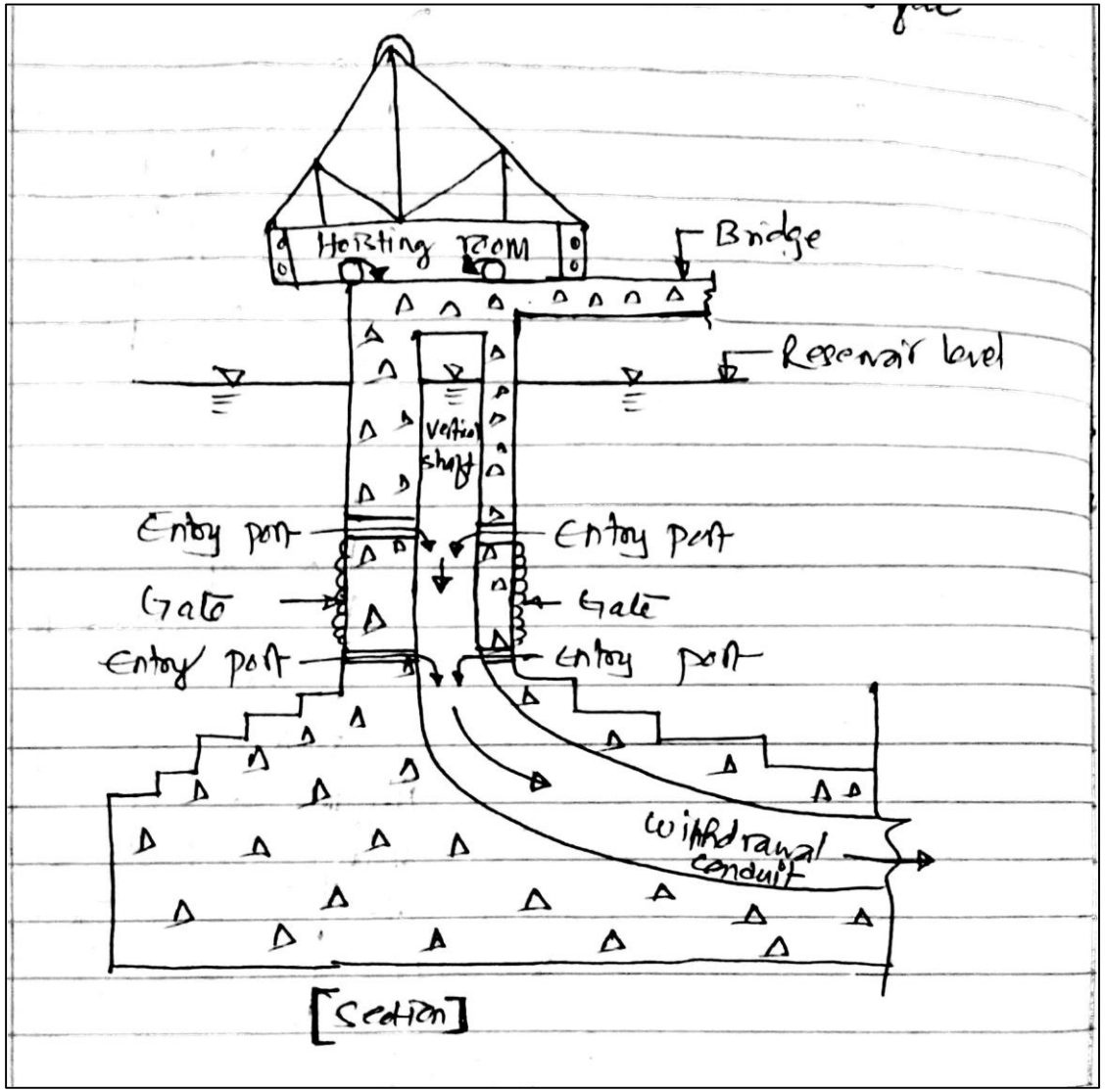
(i) Dam intake:

- It is used in high head plant
- The penstock or tunnel is embedded in dam at reqd. level



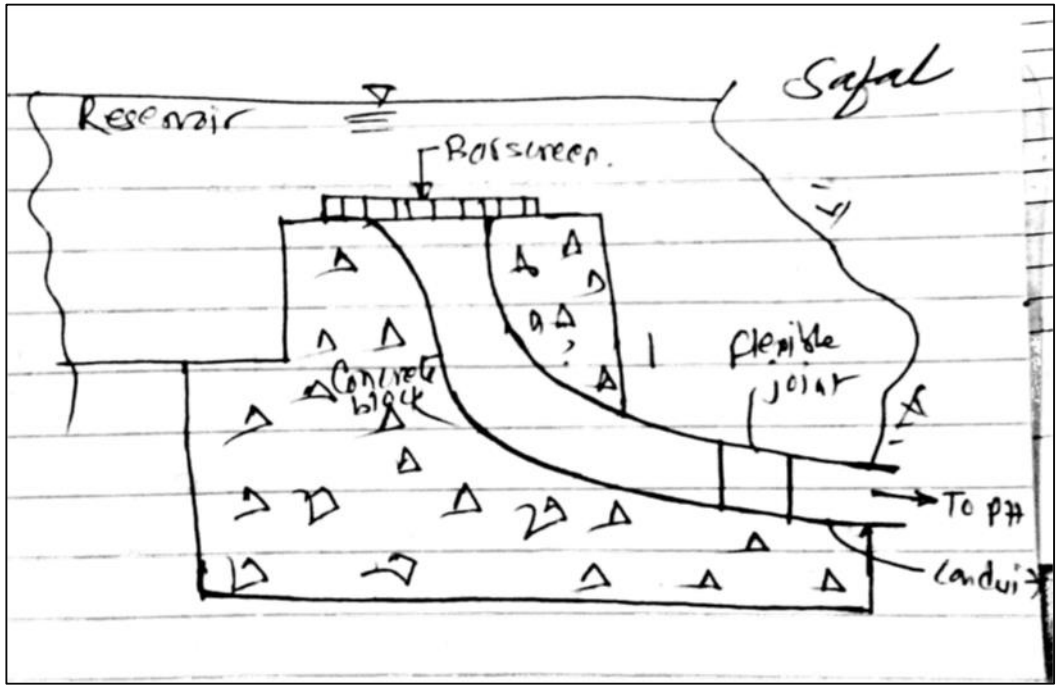


(ii)Tower intake:



-Used in large HP project
-Ports (openings) are provided at various levels

(iii) Submerged intake:



Used in low HP plant which does not have lots of sediment.

❑ Settling basin (or Desander):

Main object of settling basin is to remove the suspended particle of particular size which causes wear and tear effect on turbine and its accessories.

❖Classification of settling basin:

a. Based on flushing system:

1. Periodic type :

Advs: No loss of water.

Disadvs: generation loss during flushing.

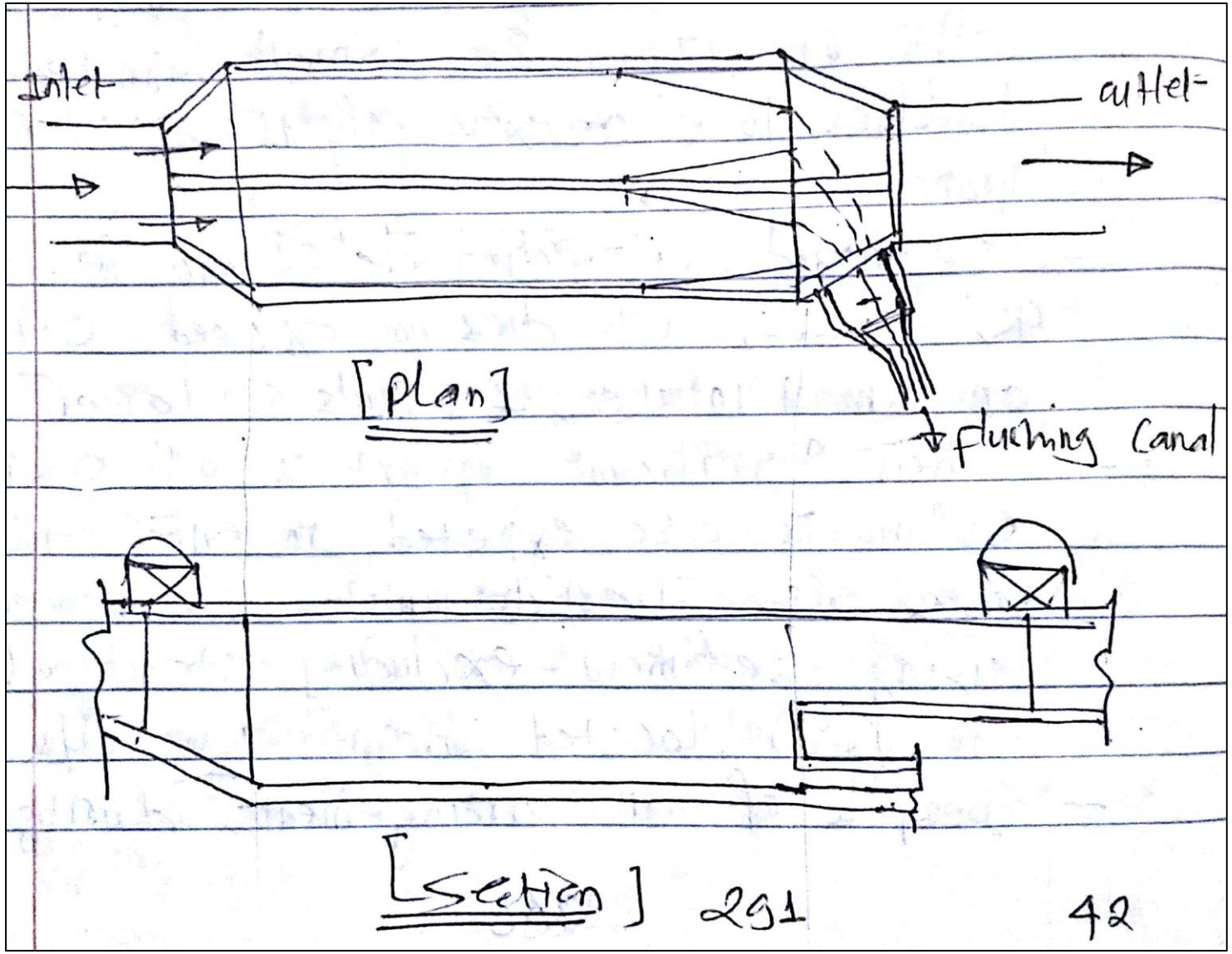
2. ***Continuous type:***

Advs: No generation loss.

Disadvs: continuous loss of water during flushing.

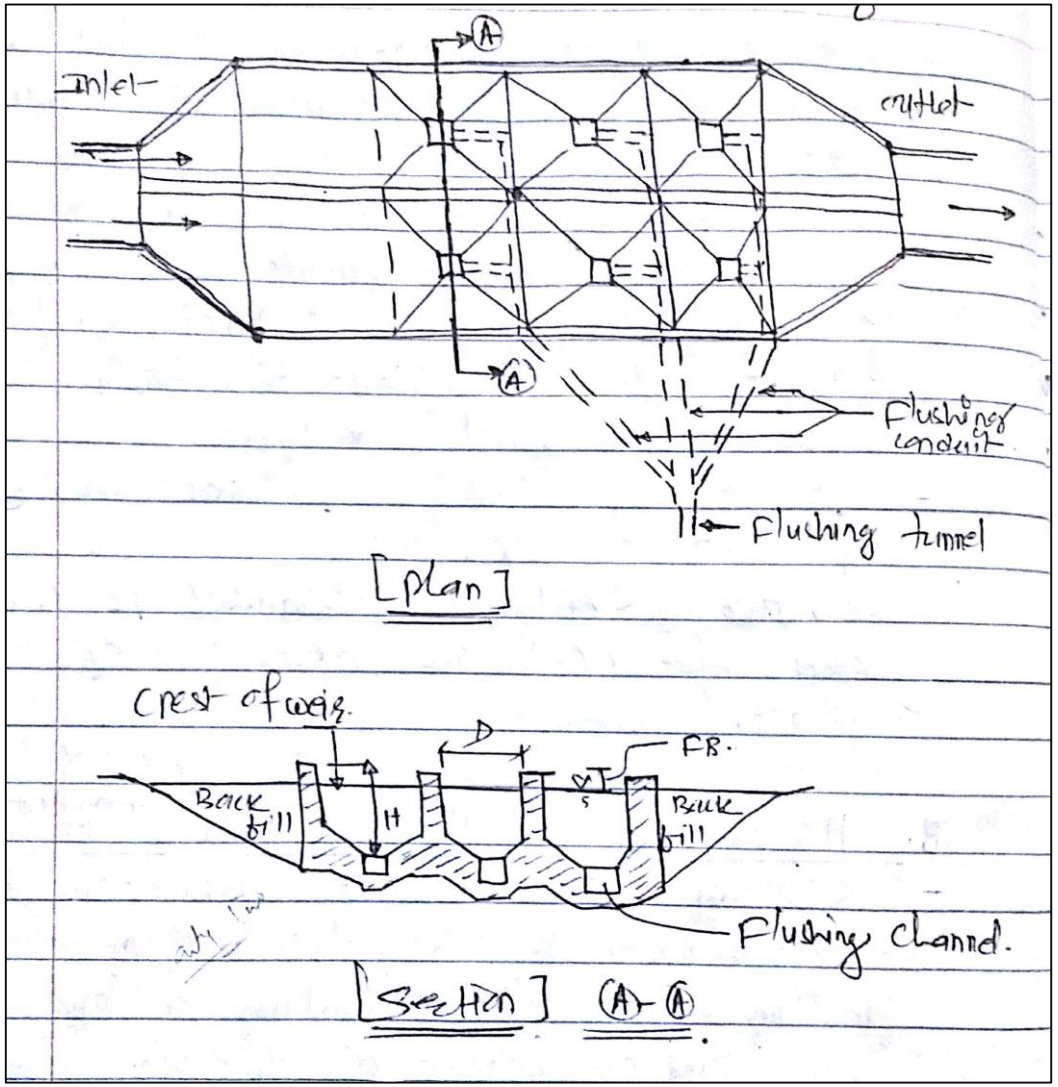
b. Based on prominent feature:

1. Conventional type:



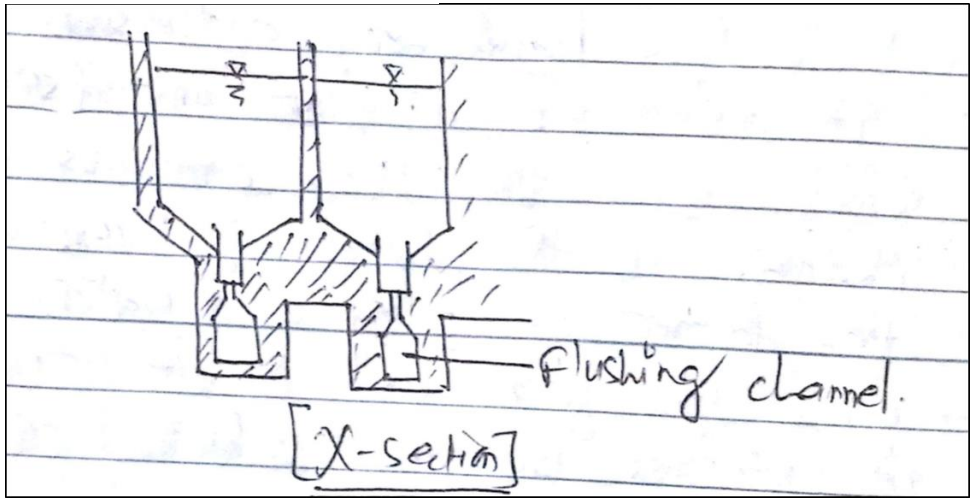
- Sediment may be removed manually or with mechanical equipment after the basin is dewatered.
- Deposited sediment may also remove by lowering water level inside the basin & generating swift flow in free surface gravity flow throughout the basin (i.e. **conventional flushing system**)
- Two settling chamber is constructed for continuous operation of plant.

2. Hooper type:



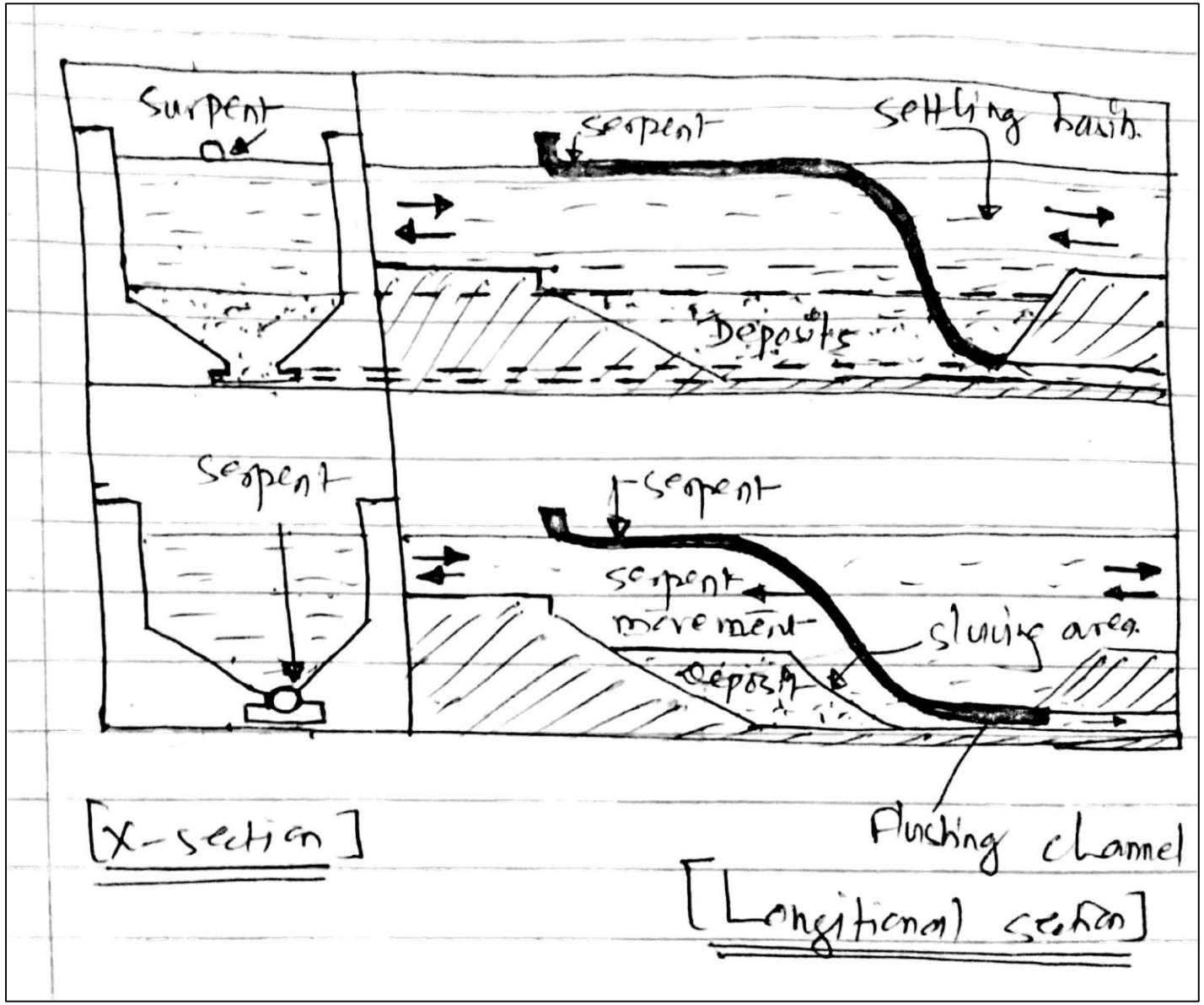
- Continuous flushing type
- Deposited sediment removed continuously from bottom opening (i.e. Hooper) (Eg. Sunkoshi (10.05MW))

3. Bieri type:



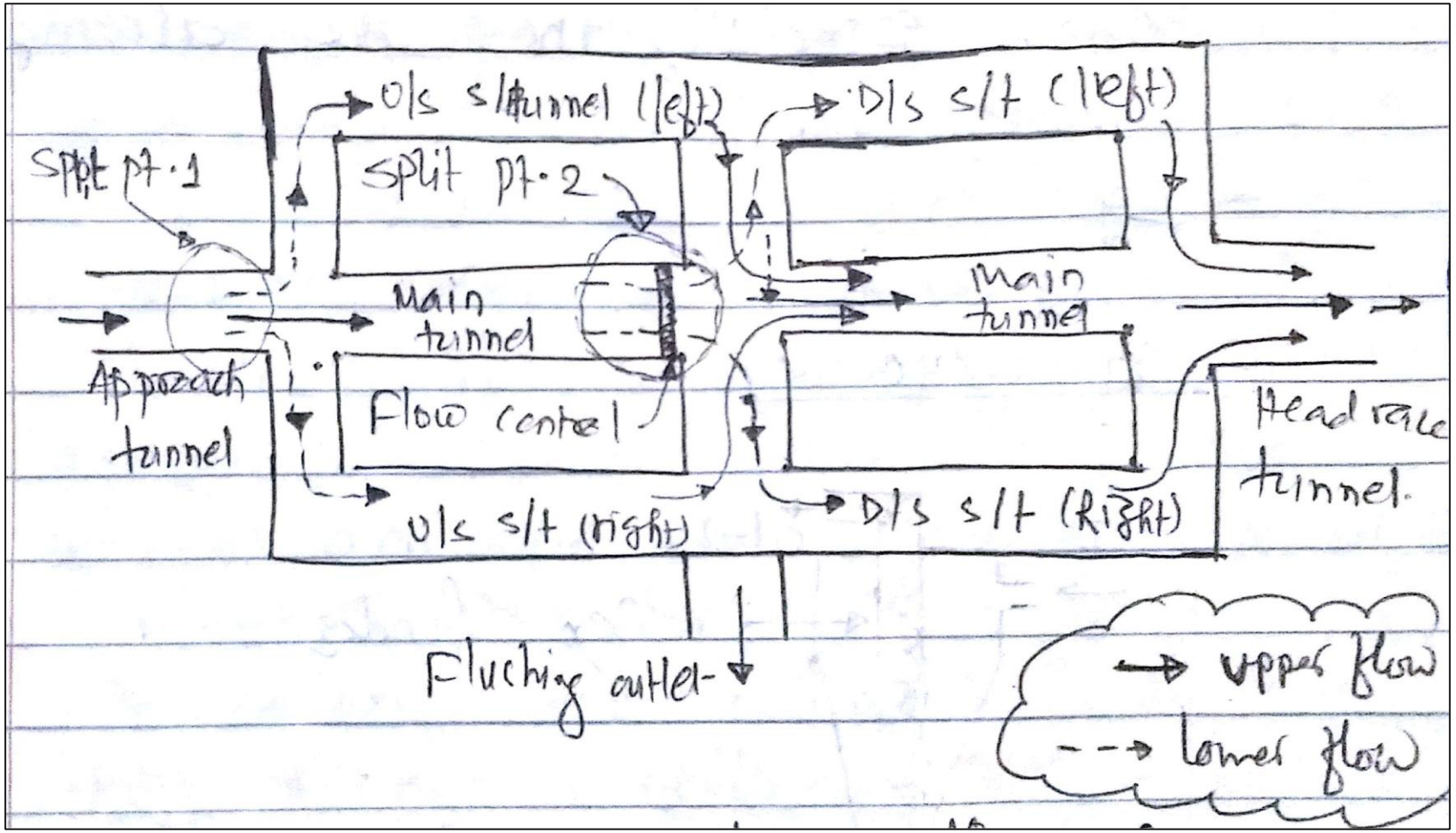
- Developed form of Hopper type, which facilate to control the loss of water during flushing.
- Two horizontal shutters are used on the bottom. Lower one is fixed and upper one is moved horizontally.
- Once the sediment collected increases the desired level, upper shutter moved over lower shutter & sediment is flushed out.
- Finally, shutter is again moved & flushing operation stopped.
- -Eg Middle marsyangdi (70MW)

4. Serpent sediment sluicing system (S4):



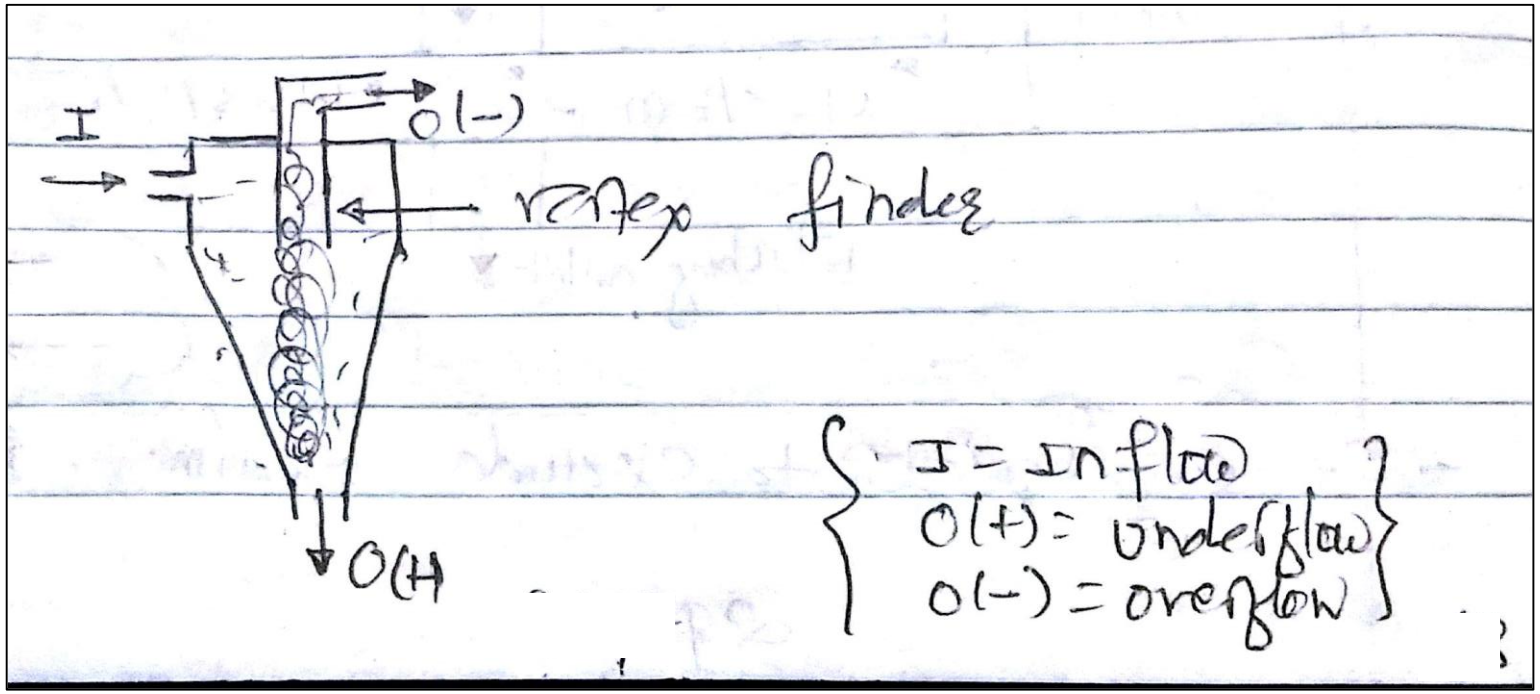
- Developed form of Hooper type and Bieri type. The major drawbacks of Hooper (continuous loss of water) and Bieri (difficult to operate shutter) have been addressed.
- It consists of a float unit (i.e. serpent), which covers the flushing channel at the bottom of basin while the former is filled with water.
- Once the serpent is dewatered, it becomes buoyant, which facilities flushing of sediment by opening the flushing channel.
- Once the flushing is over, the serpent is filled with water, which causes it gradually to sink & close to flushing channel.
- S4 system does not require any machinery or energy input as it operates under gravity force.
- Eg. Aandhikhola (5.1MW), Khimti(60MW), Jhimruk (12.5MW)

5. Split & settle:



- The concentration of sediment is much higher close to bottom of channel compared to upper layer.
- The dirtiest water (i.e. bottom layer) is diverted to the settling tunnel (s/t) constructed parallel to main conveyance.
- The relatively clean water(i.e. upper layer) is conveyed to power house.
- This concept saves the cost of settling basin.
- Especially they are arranged underground.

6. Hydrocyclone:



- Materials (i.e. sediments) that are denser than the carrier material medium (i.e. water), are separated from the stream & an be removed through overflow pipe.
- The sediment particles present in the flow move along a helicoidal path toward the orifice, thereby obtaining a long settling length compared to dimensions of separators.
- It removes particles from 5μm to 300μm.

- It utilizes centrifugal force to accelerate the settling rate of particles.
- Conical shaped vessel, joined to cylindrical section, which has a tangential feed inlet.
- The overflow pipe is extended to body know as vortex finder, to prevent short circuiting of feed directly to the overflow.
- A higher velocity flow stream is introduced tangentially into a cylindrical body having an orifice at its bottom. This gives the forced vortex near the orifice and free vortex forming in the outer periphery. As a result, sediment concentration gradient builds up across the vortex.

❑Parameters of settling basin:

1. Fall velocity /settling velocity (ω):

It depends on

- Shape & size of particle, Weight of particle and Viscosity

❖Fall velocity:

S.N.	Laws of equation ω(mm/sec)	Application range	
		Reynolds no (Re)	Diameters (d) , mm
1	$\omega = \sqrt{\frac{10}{3} g d (S-1)}$	Re> 10,000	d > 1
2	$\omega = \sqrt{\frac{4}{3C_d} g d (S-1)}$ Where, $C_d = \frac{24}{Re} + \frac{3}{\sqrt{Re}} + 0.34$	1 < R e < 10,000	0.1 < d < 1
3	$\omega = 418 d d (S-1) \frac{(3t+70)}{100}$ Where, t is in ℃	Re < 1	d < 0.1

- $Re = \frac{\omega d}{\nu}$

Where, ν =Kinematics viscosity
(use, $\nu = 0.9 mm^2/sec$, if not given)

2. **Concentration of flow /Turbidity (C):**

The amount of sediment contained in unit volume of water is called turbidity.

- C ⇑, ω ⇓

- If C > 2000 ppm, then ω reduces by 10% [1000ppm = 1kg/m^3]

3. Turbulence (T):

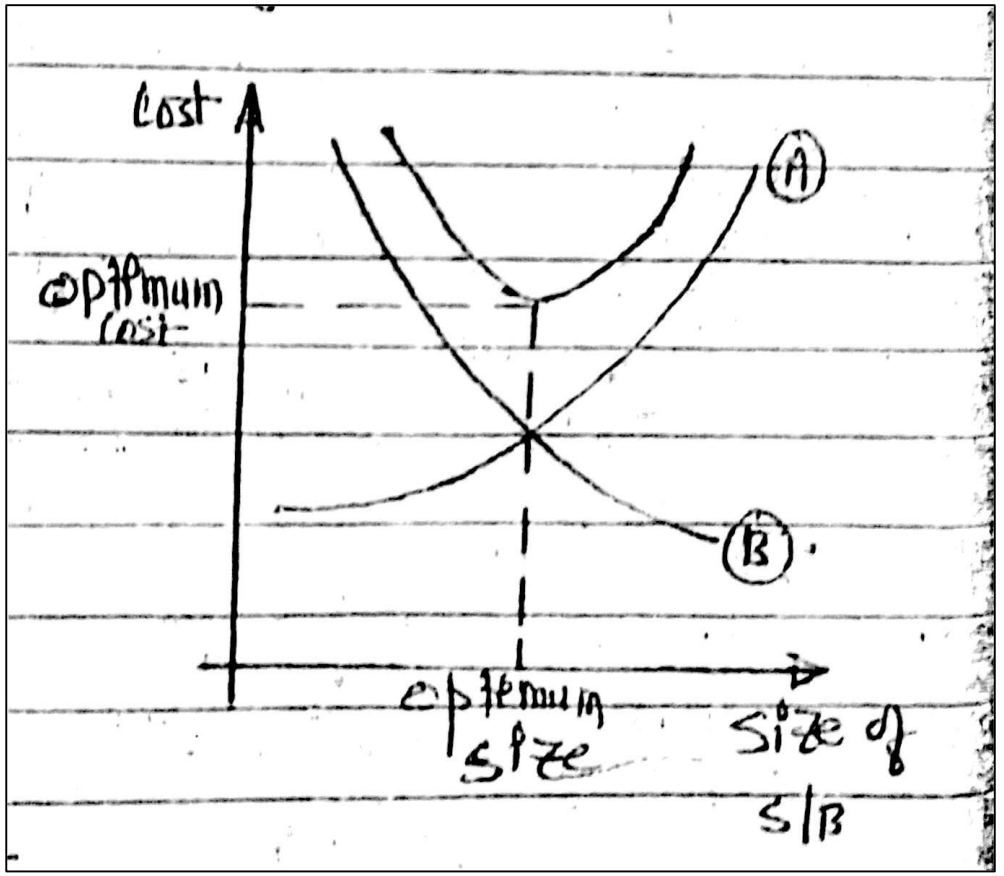
- T ⇑, ω ⇓

❑**Design criteria of settling basin (S/B):**

(A): - Cost of S/B

(B): - Cost of Turbine & its accessories w.r.t. wear & tear (i.e. loss of efficiency)

- Cost of overhauling & replacement
- Cost of generation loss due to pH shut down.



❑ Design of S/B:

1. Concentration approach:

The S/B is designed in such a way that the desired trap efficiency is achieved.

Camp's method:

$$\eta = f\left[\frac{\omega A_s}{Q}, \frac{\omega}{u_*}\right]$$

Steps:

1. Given: Trap efficiency (η), Q

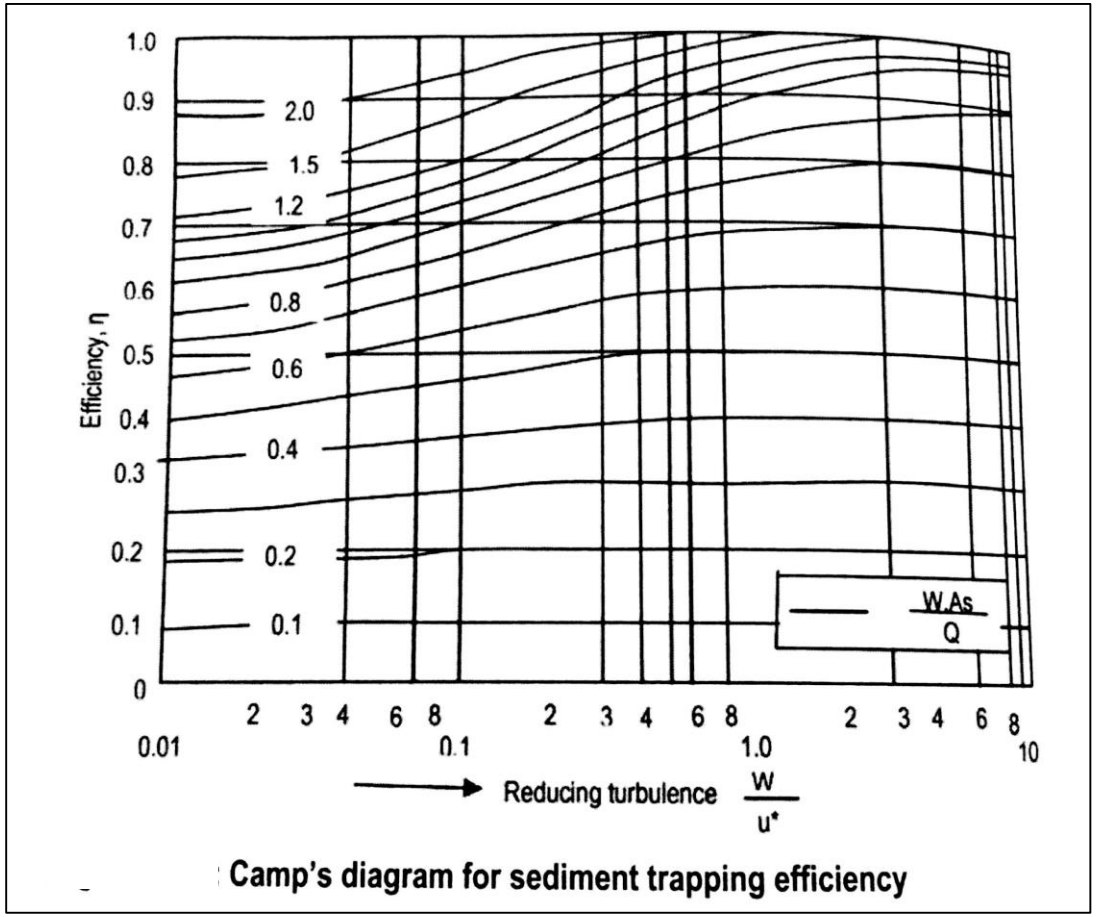
2. Assume depth of S/B (h ≈ 3-4m)

3.Compute $\frac{\omega}{u_*}$

Here, $u_* = \sqrt{\frac{\tau_0}{\rho}} = \sqrt{\frac{\gamma R S_0}{\rho}} = \sqrt{gRS_0}$

R= Hydraulic radius = A_{wetted}/P_{wetted}

S_0= Bed slope, u_* = shear velocity



Camp's diagram for sediment trapping efficiency

4. From known value 'η' & $\frac{\omega}{u_*}$, find the value of $\frac{\omega A_s}{Q}$

5. Then From the value of ω^* and Q, find the value of A_s. $[A_s = surface\ area = LB, use\ \frac{L}{B} = 10]$

6. Final dimension: $\boldsymbol{L \times B \times h}$

2. Particle approach:

The S/B is designed in such a way that time required for travelling & settling for reference particle is just equal.

Assumption: steady flow, Quiescent flow (No turbulence)

a. Without considering turbulence:

Steps:

1. Assume depth of S/B (h) (h= 3-4m)

2. Now, we know;

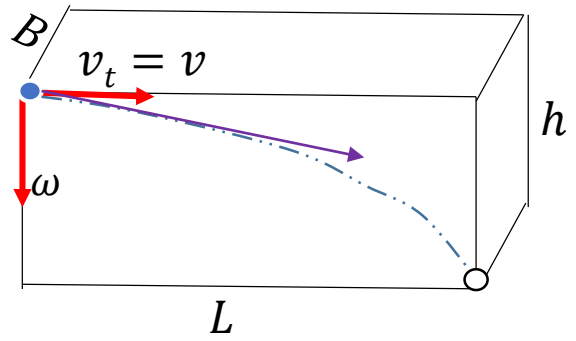
$t_t = t_s \quad \Rightarrow \frac{l}{v} = \frac{h}{\omega} \qquad \therefore l = \frac{vh}{\omega}$ .....(i)

3. $v = a\sqrt{d}$ (cm/sec), But use 'd' in mm

Here, a = 36, if d> 1mm

= 44, if 0.1 < d <1mm

= 51, if d < 0.1mm



4. Find the value of l from the eqn. (i)

5. Find the width of S/B

From continuity equation,

$Q = Av = Bh.v \qquad \therefore B = \frac{Q}{vh}$

6. Final dimension: $\boldsymbol{L \times B \times h}$

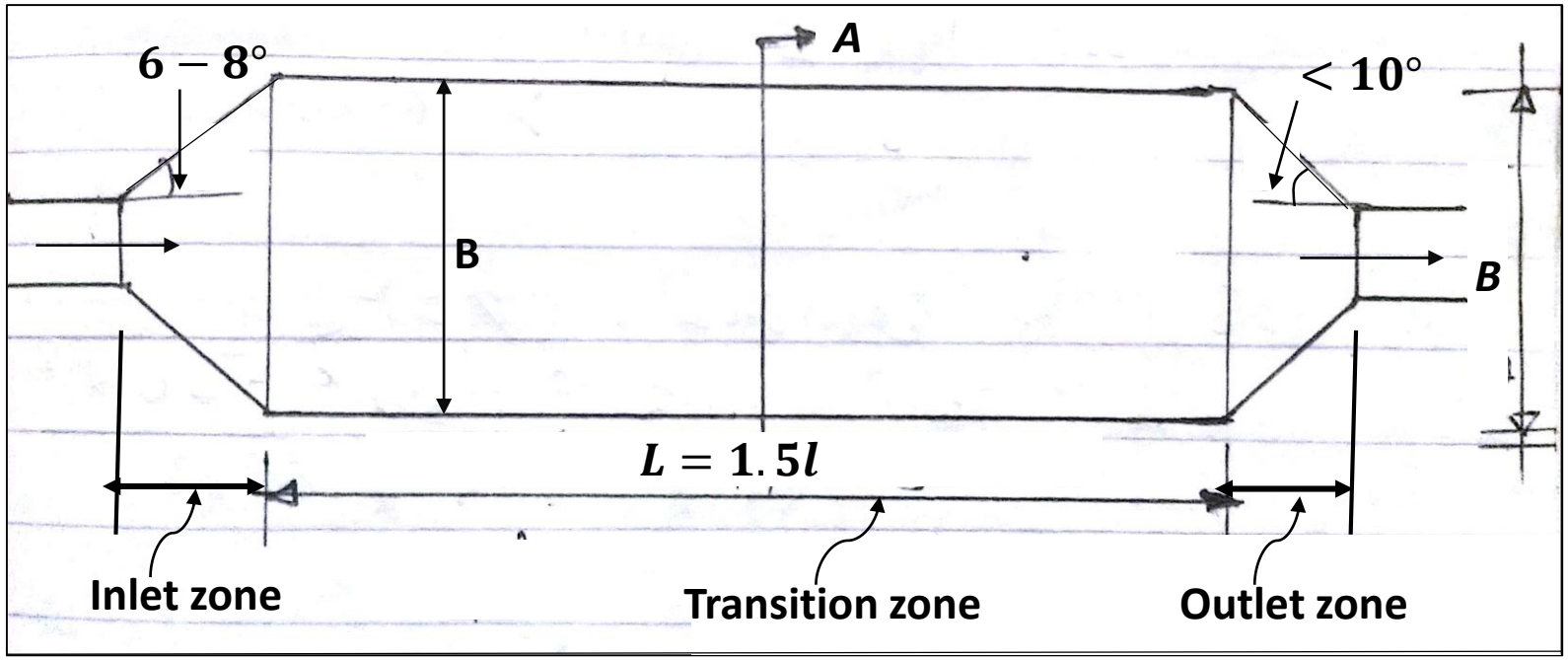


Fig: Plan of S/B

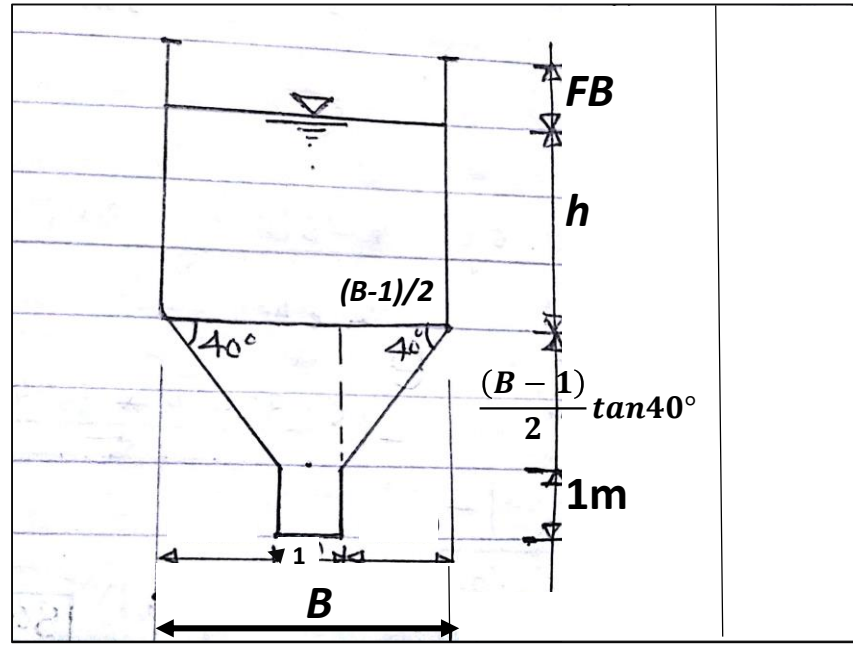


Fig: X-section A-A

b. With considering turbulence:

$t_t = t_s \quad \Rightarrow \frac{l_t}{v} = \frac{h}{\omega - \omega'} \quad \therefore l_t = \frac{vh}{\omega - \omega'}$ .....(i)

Here, ω' = Reducing fall velocity

$\omega' = \alpha v$ (cm/sec), (v in cm/sec)

$\alpha = \frac{0.132}{\sqrt{h}}$ (h in m)

Final dimension : $\boldsymbol{L_t \times B \times h}$ (Since, $L_t = 1.5 l_t$)

Q.No.1) Design a settling basin for the high head plant by using following data:

Diameter of particle = 0.5mm

Design discharge = $5m^3/sec$

Depth of S/B = 3.2m

Specific gravity of particle = 2.65

a) Neglecting turbulence of flow
b) Considering turbulence of flow
c) Check the length of basin by using M.A. Valikanov's relation.
d) Check the efficiency of basin by using vetter's equation, while the trapped efficiency at critical condition is 85%.

(**Note:** *For (c),* $L_{val} = \frac{\lambda^2 v^2 (h^{0.5} - 0.2)^2}{7.51\omega^2}$*, use* λ *= 1.5 & 1.8 for 97% removal & 100% removal of particle. In this question, compare '*L_{val}*' with length '*l*' finding from without considering turbulence case.*

For (d), find the 'η*' from* $(1 - \eta) = e^{-\frac{wAs}{Q}}$*, and compare with 85% as given by question but use length '*l*' finding from without considering turbulence case.***)**